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ON THE CAUSES OF THE SUN'S EQUATORIAL ACCELERATION AND THE SUN-SPOT PERIOD.

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In the beginning of every science isolated facts present themselves, which apparently have no connection with each other. As the science is gradually perfected, relations are found between the different phenomena, the subject becomes more complex, and covers a wider stretch than it did at first; but at the same time it becomes easier to understand because it is found that all of the phenomena, which have been observed, are but the consequences of certain fundamental laws. In solar physics two laws of fundamental importance have been found, the law of the equatorial acceleration and that of the periodicity of sun-spots. Their great significance lies in this, that they give numerical relations between measurable quantities, and that their consequences can, therefore, be deduced by mathematical reasoning.

The researches which I have made upon this subject have appeared in my inaugural dissertation on "Hydrodynamische Untersuchungen mit Anwendungen auf die Theorie der Sonnenrotation," Berlin, 1897, and in some papers in the *Astrophysical Journal*. A brief account has also appeared in the *Astronomical Journal*, Vol. XVIII, No. 416. In this paper I will try to present the principal points in popular language.

We assume the Sun to be a fluid body, the general term fluid comprehending both gaseous and incompressible fluids as special cases. Its present condition and the present motion of its parts are, then, but the consequences of the condition of the nebula from which it has been formed, and of the motion of the parts of this

nebula. This is exactly the same as in the case of planetary orbits. The form of the planet's orbit and its position in space was determined by the position and the motion of the planet at the time of its formation. Such an orbit must be a conic section, if we neglect the perturbations, and it may possibly be a circle. And just in the same way as a circular orbit is an exception in the case of planetary orbits, only one occurring among an infinite number, so also is it infinitely improbable that a gaseous body starting to rotate should rotate in the same way as a solid mass. It may do so, but in general it will not.

But obviously we must take into account the influence of the internal fluid friction, which, of course, tends to make the body rotate as if it were solid. But the mathematical theory shows this influence to be very small, so small that it will not change the daily arc described by a point upon the Sun by 2′ in 27,500,000 years.

This result is obtained in the course of investigating the following problem. All particles of a viscous fluid describe circles in parallel planes around an axis perpendicular to these planes. The conditions for the motion and figure of such a body are investigated. The angular velocity of rotation is supposed to be different in different parts of the fluid. It is found that an important theorem holds, which we proceed to explain.

The density of the body, as well as the temperature may vary from point to point. All points in which the density has the same value constitute, in general, a surface which is called a surface of constant density. Similarly we can speak of surfaces of constant temperature. The theorem which we have in view is this:—

In a rotating viscous fluid, the angular velocity of rotation is the same for all points whose distance from the axis of rotation is the same, if the surfaces of constant density and of constant temperature coincide. If we conceive the axis of rotation to be surrounded by a family of co-axial cylinders, the surface of each cylinder rotates as if it were rigid.

This theorem is shown to be very probably true for the case of the Sun, and the surfaces of constant density are calculated approximately. By applying the theorem to the comparison of the different laws of rotation which have been empirically found for the sun-spots, for the faculæ and for the so-called reversing layer, the difference in level of these different solar strata can be

ascertained. The discussion of these numbers leads to the result that the solar atmosphere, i. e. the region above the "photosphere" is much more extensive than has usually been believed. The contradictions, which seem to rise herefrom at first sight, can be easily cleared up if the power of refraction, which this atmosphere must have, is taken into account. One other important conclusion is that the sun-spots must be higher up in the solar atmosphere than the photosphere, a view which, while opposed to the classical idea of WILSON, is nevertheless constantly gaining more adherents.

If the motion of the solar particles is not strictly uniform and circular, and it is easy to see that in general it will not be so, the deviations from the uniform circular motion cause corresponding changes in the temperature, pressure and density, as the equations show. Now it is quite easy to show that these deviations, supposed to be small in comparison with the principal motion, are of an oscillatory character, tending at the same time towards zero. That is, they will be periodic functions of the time but become constantly smaller, in the same way as a pendulum swinging in air oscillates backward and forward, but finally comes to a stop. But in our case this dampening effect is only very slight, and may not be noticed for thousands of years. To the periodic variations of the motion will then correspond periodic changes in temperature, etc., and it is extremely plausible that hereto will correspond periodic variations of the Sun's activity. This line of thought gives a very reasonable explanation of the sun-spot period, which is also supported by some numerical work which is meant to show that the causes invoked are sufficient to explain the observed phenomena.

If we remember that the theory sketched out here is based on no arbitrary assumptions, that it reaches its conclusions by rigid mathematical reasoning, and that it succeeds in uniting the observations of solar physicists, which have been the source of so many wild hypotheses, into one consistent whole, it certainly seems to be a step in the right direction. And it seems to me that we are justified in saying that the rotation-law is the instrument with which to fathom the solar mysteries. It is the fundamental law to which all others, even that of the sun-spot period, are but supplementary.

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